Introduction

1.1 Overview

In today's climate of growing energy needs and increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. One such alternative is solar energy.

The use of renewable energy sources will increase, leading to a more sustainable energy mix, reduced greenhouse gas emissions and a lower dependency from oil.

Despite having public support and advantages over other energy sources, renewable technologies have been repeatedly characterized as unable to meet our energy needs. People have been presented only a choice between conventional fossil fuels and nuclear power. This, however, is a false choice. Renewable energy can reliably generate as much energy as conventional fuels, and can do so without producing carbon emissions or radioactive waste.

Energy resources are commonly classified as:

1- Renewable energy resources

2- Non-Renewable energy resources

1.2 Non-Renewable energy resources

A non-renewable resource is a natural resource which cannot be produced, grown, generated, or used on a scale which can sustain its consumption rate, once depleted there is no more available for future needs. Also considered non-renewable are resources that are consumed much faster than nature can create them. Fossil fuels (such as coal, petroleum, and natural gas), nuclear power (uranium) and certain aquifers are examples. In contrast, resources such as timber (when harvested sustainably) or metals (which can be recycled) are considered renewable resources.

1.3 Renewable energy

Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished). About 16% of global final energy consumption comes from renewables, with 10% coming from traditional biomass, which is mainly used for heating, and 3.4% from hydroelectricity. New renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels) accounted for another 3% and are growing very rapidly. The share of renewables in electricity generation is around 19%, with 16% of global electricity coming from hydroelectricity and 3% from new renewables.

Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources.

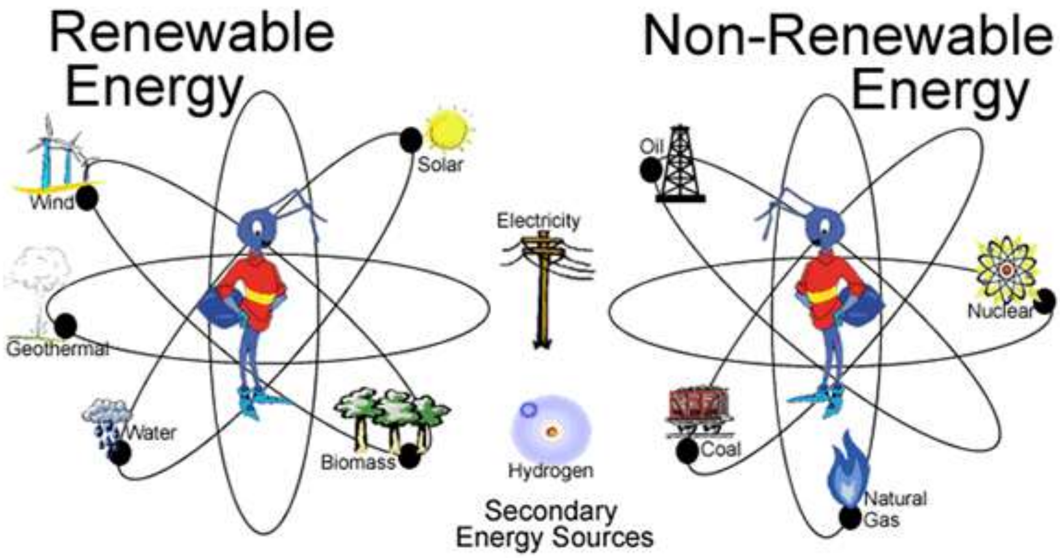

Figure 1.1 Forms of renewable energy and non-renewable energy

1.3.1 Basic forms of renewable energy:

Wave

Waves are created by the wind blowing across the sea and by the gravitational force of the moon. Wave power uses the energy of the waves to turn turbines that make electricity.

Figure 1.2 Wave energy

Geothermal

Geothermal power uses the heat that comes from deep rocks under the surface of the Earth. The temperature of the Earth increases towards its center. The hot water or steam that comes from deep within our planet can be used to make electricity.

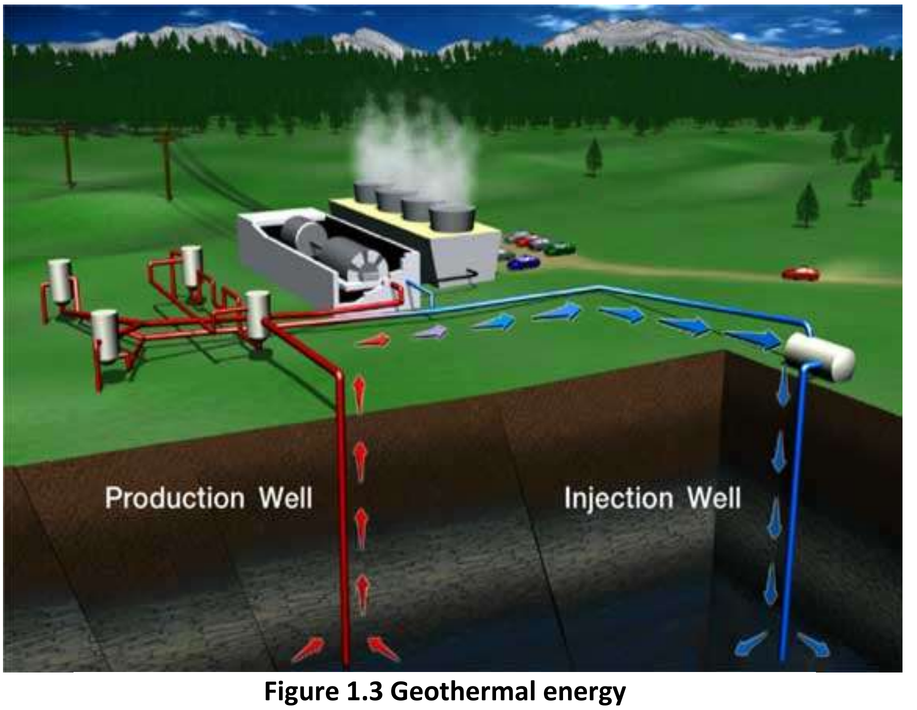

Figure 1.3 Geothermal energy

Hydro-electric

Hydro-electricity is generated from running water. Dams are built across a lake or river in a valley to trap water. The water flows through tunnels and turns the turbines which make electricity.

Figure 1.4 Hydro-electric energy

Solar

The Sun releases an amazing amount of energy due to the nuclear fusion of hydrogen taking place within its core. Solar panels, called photovoltaic cells are used to convert the Sun' s energy into electricity. The Sun can also be used to heat water passing through special solar collectors.

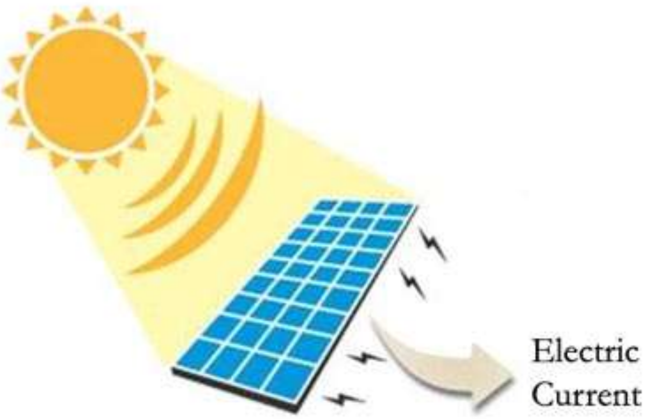

Figure 1.5 Solar energy

Wind

Wind is made when the Sun heats the Earth and the area above land gets hotter than the area above water. The hot air above land rises upwards leaving an area of low pressure. Cooler air moves into this area of low pressure making wind which we use to turn wind turbines and make electricity. Wind used to be used to turn windmills to grind wheat into flour.

Figure 1.6 Wind energy

Biomass

Biomass uses the energy from plants and waste materials to make electricity. For example, wood or animal droppings can be burnt to make steam that turns turbines to make electricity.

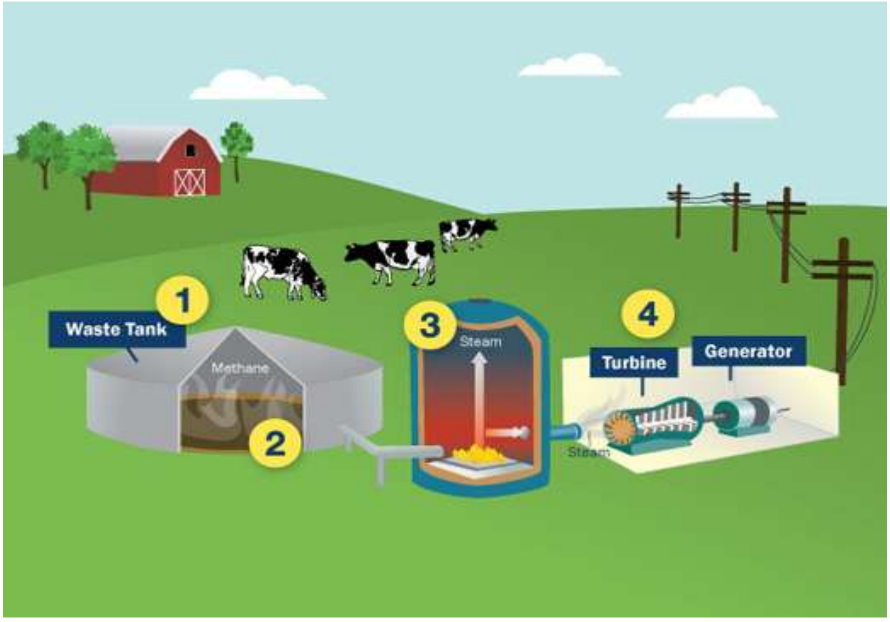

Figure 1.7 Biomass energy

Tidal

Tidal energy comes from the movement of water in the sea by the tides. These tides happen twice a day. The flow of water that is created by the tides is used to turn generators that make electricity.

Figure 1.8 Tidal energy

1.4 Energy Conversion

Energy transformation is when energy changes into another form. In physics, the term energy describes the capacity to produce certain changes within a system, without regard to limitations in transformation imposed by entropy. Changes in total energy of systems can only be accomplished by adding or subtracting energy from them, as energy is a quantity which is conserved, according to the first law of thermodynamics. According to special relativity, changes in the energy of systems will also coincide with changes in the system's mass, and the total amount of mass of a system is a measure of its energy.

Energy in a system may be transformed so that it resides in a different state, or different type of energy. Energy in many states may be used to do many varieties of physical work. Energy may be used in natural processes or machines, or else to provide some service to society (such as heat, light, or motion). For example, a solar cell converts solar radiation into electrical energy that can then be used to light a bulb or power a computer.

The generic name for a device which converts energy from one form to another is a transducer.

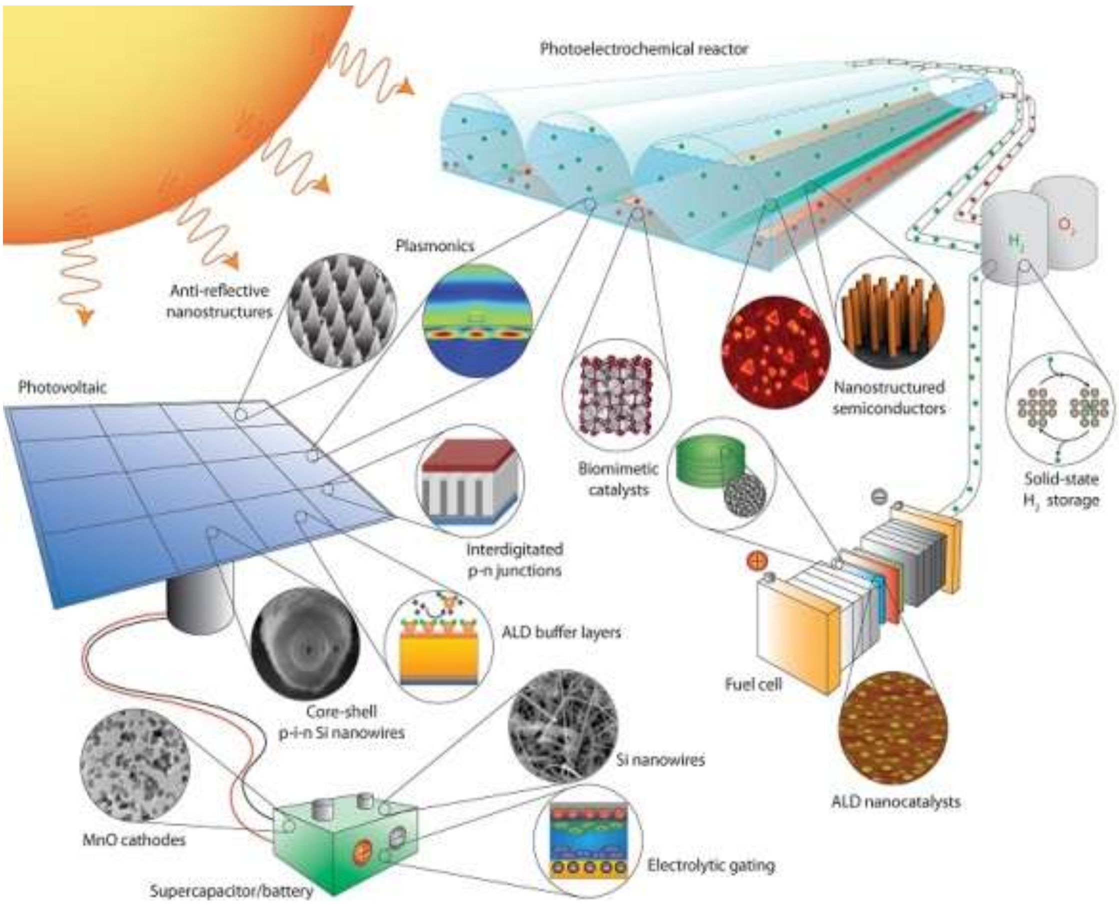

Figure 1.9 Examples of energy conversion

1.5 Solar Energy

Solar energy, radiant light and heat from the sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar energy technologies include solar heating, solar photovoltaic, solar thermal electricity and solar architecture, which can make considerable contributions to solving some of the most urgent problems the world now faces.

Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air.

The Earth receives 174 petawatts (PW) of incoming solar radiation (insolation) at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The spectrum of solar light at the Earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet.

Earth's land surface, oceans and atmosphere absorb solar radiation, and this raises their temperature. Warm air containing evaporated water from the oceans rises, causing atmospheric circulation or convection. When the air reaches a high altitude, where the temperature is low, water vapor condenses into clouds, which rain onto the Earth's surface, completing the water cycle. The latent heat of water condensation amplifies convection, producing atmospheric phenomena such as wind, cyclones and anti-cyclones. Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14 °C. By photosynthesis green plants convert solar energy into chemical energy, which produces food, wood and the biomass from which fossil fuels are derived.

The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 exajoules (EJ) per year.

Solar energy can be harnessed in different levels around the world. Depending on a geographical location the closer to the equator the more "potential" solar energy is available.

Table 1.1 Yearly Solar Fluxes & Human Energy Consumption

Yearly Solar Fluxes & Human Energy Consumption	
Solar	3,850,000 EJ
Wind	2,250 EJ
Biomass	3,000 EJ
Primary Energy(2005)	487 EJ
Electricity(2005)	56.7 EJ

Solar energy technologies convert the sun’s light into usable electricity or heat. Solar energy systems can be divided into two major categories: photovoltaic and thermal. Photovoltaic cells produce electricity directly, while solar thermal systems produce heat for buildings, industrial processes or domestic hot water. Thermal systems can also generate electricity by operating heat engines or by producing steam to spin electric turbines. Solar energy systems have no fuel costs, so most of their cost comes from the original investment in the equipment.

1.5.1 Solar thermal energy

Direct-use thermal systems are usually located on individual buildings, where they use solar energy directly as a source of heat. The most common systems use sunlight to heat water for houses or swimming pools, or use collector systems or passive solar architecture to heat living and working spaces.

1.5.2 PV Systems

Photovoltaic (PVs) convert sunlight directly into electricity, using semiconductors made from silicon or other materials. A photovoltaic (PV) or solar cell is the basic building block of a PV (or solar electric) system. An individual PV cell is usually quite small, typically producing about 1 or 2 watts of power. To boost the power output of PV cells, we connect them together to form larger units called modules. Modules, in turn, can be connected to form even larger units called arrays, which can be interconnected to produce more power, and so on.

1.6 Thermal photovoltaic (PVT):

PVT is defined as a device using PV as a thermal absorber. By using the heat generated in the PV, a PVT device generates not only electrical, but also thermal energy, in which PV is installed next to solar thermal in the same frame.

PVT devices can be very different in design, ranging from PVT domestic hot water systems to ventilated PV facades and actively cooled PV concentrators. In order to indicate the range of devices classified as PVT, some pictures of PV devices are shown in Figure 1.1 below. The markets for both solar thermal and PV are growing rapidly and have reached a very substantial size. For PVT a similar growth can be expected; the technical potential of the technique is large, especially if the market for domestic applications can be reached. Given the broad range of application for PVT, which is not only suitable for domestic hot water heating (glazed PVT collectors), but also for offices (ventilated PV for preheating ventilation air during winter and providing the driving force for natural ventilation during summer), the market for PVT might even be larger than the market for thermal collectors.

Figure 1.10 Some PVT devices

However, the present PVT market is still very small. PVT air facades have only been applied in a few special projects, and only recently a first standardized product has been developed. Three commercial PVT air collector manufacturers exist, but, apart from the summer cottage market, the number of PVT air collectors installed is very small. With respect to PVT-liquid collectors, at present only two manufacturers of unglazed PVT collectors exist. Although several manufacturers have tried to commercialize glazed PVT-liquid collectors, a commercial product has only very recently become available. Finally, three commercial companies supply PVT concentrators. It is the aim of this roadmap to boost the attention for PVT, in order to change this situation.

1.7 Literature Review:

Several reports and papers exist within the field of PV/T collectors. The majority of the published papers and reports are concerning theoretical developments of the efficiency of PV/T collectors. In the following only a few of these reports and papers are considered.

In this project an experimental model of a PV/T collector was constructed and measured. The model consisted of a conventional solar thermal collector with PV cells pasted to the absorber. One of the main conclusions from this study is that the thermal bonding between PV cells and absorber plate is very important for the thermal efficiency. The electrical efficiency is reduced when the flow rate of the cooling fluid is low, because the PV cells near the outlet then became relatively warm, and thus having a lower electrical output. Several authors have contributed to this report, which also describe experimental results. The main conclusion is that most PV/T collectors have same thermal characteristics than ordinary nonselective thermal solar collectors. In this report the evaluation of PV/T collectors is also discussed, and the exergy method is suggested as one of the ways to compare different constructions. The authors of this report have adopted the method.

Ecofys energy and environment has performed a technology survey on hybrid PV/T systems. This survey was performed in a joint research with the Eindhoven University of Technology (EUT) and the Dutch centre for applied Physics (TNO) and funded by Novem. The research consisted of two parts: a literature survey and the development and assessment of a evaluation method on PV/T systems. The major findings of this study will be presented, with a strong emphasis on the market assessment

This is an EU Joule project that has carried out extensive studies of PV/T systems, in particular PV modules with ventilated air behind the PV cells for cooling the PV cells. The project involved practical measurements as well as theoretical work and simulations with the ESP-r program developed for passive solar heating. Eight different (office) buildings at different locations in Europe were selected for a total simulation of energy usage. The conclusions were that in southern/mid Europe, and in buildings with a modest fresh air demand, the savings are negligible. In Northern Europe, and for buildings with a high and constant fresh air demand, the savings are up to 10% of the annual heating demand. The effect on the electricity production caused by cooling the PV cells is very

small.

Bergene and Lovik (1995) have shown theoretically that a total efficiency of 60–80% can be achieved with a PV/T collector. The recent test result (Fujisawa and Tani, 1997) shows that a thermal efficiency of 60% can be obtained for a PV/T collector.

B.J. HUANG (1999) has introduced the concept of primary-energy saving efficiency for the evaluation of a PV/T system. The primary-energy saving efficiency of the present IPVTS exceeds 0.60. This is higher than for a pure solar hot water heater or a pure PV system. The characteristic daily efficiency η^* reaches 0.38 which is about 76% of s the value for a conventional solar hot water heater using glazed collectors (η^* 0.50).

S. Kalogirou1 and Y. Tripanagnostopoulos (2005) the results show that the electrical production of the system, employing polycrystalline solar cells, is 532 kWh, 515 kWh and 499 kWh and the solar thermal contribution is 0.686, 0.564 and 0.293 for the three locations respectively. The respective results for the system employing amorphous silicon cells are 260 kWh, 251 kWh, 224 kWh and 0.726, 0.601 and 0.341 for the three locations respectively. A non hybrid PV system produces about 30% more electrical energy but the present system covers also, depending on the location, a large percentage of the hot water needs of a house.

Yod Sukamongkol, Supachart Chungpaibulpatana and Bundit Limmeechokchai (2006) have showed that the useful energy from PV/T collector and condensing unit of air conditioning system can heat the circulating air up to 50 °C with 20% relative humidity. Moreover, the PV cooling can increase the electrical efficiency of PV cells and also increasing the total efficiency of the PV/T modules while the silica gel dehumidification unit can save the electrical energy used in the air conditioner up to 20%.

Yasutomi MIKI (2007); The following result have been obtained:

1. The 23% light shielding by Photovoltaic cell has little effect in the collecting efficiency of this hybrid air-type solar collector.
2. This hybrid air-type solar collector shows almost the same performance as compared with this solar air heater on overall energy efficiency.

P. Gang, J. Jie, H. Wei, L. Keliang and H. Hanfeng (2007) have shown that the COP of heat pump, the $COP_{p/t}$ of system and the photovoltaic efficiency of PV system are 6.3, 9.0 and 13.2% respectively. These indicated significant improvement of the performance of heat pump and the PV system.

A. Ibrahim and G.Li Jin(2009) have shown that the experiment results for the single flow absorber collector generates combined PV/T efficiency of 64% ,electrical efficiency of 11% and power maximum achieved at 25.35 W. Moreover, single pass rectangular tunnel absorber collector generates combined PV/T efficiency of 55% electrical efficiency of 10% and maximum power of 22.45W.